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ARTHRODESIS AFTER FAILED KNEE ARTHROPLASTY

A Nationwide Multicenter Investigation of 91 Cases

by

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Arthrodesis After Failed Knee Arthroplasty

A Nationwide Multicenter Investigation of 91 Cases

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Ninety-one patients with attempted arthrodesis after failed knee arthroplasty were identified in a prospective nationwide study of knee arthroplasties performed from October 1975 through January 1982 in Sweden. The study included 43 hinged or stabilized, 34 bi- or tricompartment, and 14 unicompartment endoprostheses. Three-fourths of the failures were caused by infections. At follow-up evaluation, two patients had expired from infection and four patients had amputations. Fusion was achieved in only 50% of 108 attempts in 91 knees. Patients with unstable joints had limited function. The fusion rate was relatively high after unicompartment endoprostheses, in cases with sustained rigid fixation, or in cases where infection was brought under control at arthrodesis. Rigid fixation was best achieved with an external double frame or an intramedullary nail. Repeated attempts were worthwhile. Removal of all foreign material, eradication of the infectious lesion, and an arthrodesis performed in a one- or two-stage procedure with insertion of gentamicin beads seemed to be the best way to combat infection. The treatment of prosthetic failures should be referred to centers with special interest in knee arthroplasty.

Total knee arthroplasty (TKA) has for more than a decade been the main treatment for advanced gonarthropathy. The designs of the endoprostheses and, to some extent, the indications for their use have been altered.

Reports on the life expectancy of the early designs indicate loss due to failure in one-fourth to one-tenth at five years.^{13,20} Thus, TKA results do not meet the standards of total hip arthroplasty, mainly because of the more complicated biomechanics of the knee joint. The thin soft-tissue coverage increases wound problems and susceptibility of infections. TKA failures are treated either conservatively with external supports, and in cases of infection with systemic antibiotics, or surgically with revisions, exchange arthroplasty, or ultimately with arthrodesis and amputation. Knee arthrodesis for failed TKA means sacrifice of mobility for freedom from pain, infection, or instability. Earlier reports from orthopedic centers with special interest in TKA surgery indicate that stable fusion was not as easily obtained after TKA failure as in primary arthrodesis.^{6,8,11} The importance of good bone stock, infection control, and sustained rigid fixation have been stressed.^{3,11,22}

The aim of this report is to study, on a multicenter basis in Sweden, the national overall results of arthrodesis for TKA failure related to the various techniques of obtaining fusion and combating infection.

MATERIALS AND METHODS

SELECTION OF PATIENTS

In October 1975, the Swedish Orthopaedic Society started a nationwide computer survey of TKA surgery. Today, all Swedish departments of orthopedic surgery participate in this project—

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The Swedish Knee Arthroplasty Project.² All knee arthroplasties performed after the date of onset of the project are reported for computer filing. The initial report after each TKA contains information on knee condition and the endoprosthesis used, local or general antibiotic prophylaxis, duration of the hospital stay, and local or general complications during the stay. Each patient is followed up for complications or revisions after surgery and at one, three, and six years. In January 1982, the computer file contained 6342 knee arthroplasties. At that time, 91 patients with arthrodesis for TKA failure were identified and followed up with a clinical and radiographic examination by the responsible surgeons. The clinical and radiographic material was then collected and examined by the authors.

No general principles for the choice of endoprosthesis, treatment of complications, indications for arthrodesis, or methods of achieving knee fusion were agreed upon before collecting data.

CLINICAL MATERIAL

At the time of arthrodesis there were 63 women and 28 men with an average age of 68 years, ranging from 43 to 84 years. In 45 patients the right knee was involved and in 46 the left was involved. The preoperative diagnosis was osteoarthritis in 43, of which eight were secondary to fractures of the knee and one secondary to tabes dorsalis. Forty-five patients had rheumatoid arthritis and one patient each suffered from giant cell tumor of the femoral condyle, post-traumatic knee instability, and synovitis of unknown origin.

Surgery before TKA. Before the TKA, 24 patients had had 34 surgical procedures in the involved knee. These included tibial osteotomy in 14, synovectomy in six, meniscectomy in three, patellectomy in two, revision of a supracondylar pseudarthrosis five times in one patient, removal of a bone cyst and a tumor with cancellous bone transplantation in two, and osteosynthesis of a femoral condylar fracture and a lateral patellar release in one patient each.

Earlier TKA. Twenty-four patients had had a previous TKA before the final TKA in the knee that was later fused. These TKAs had been performed with hinged endoprostheses in seven, bi- or tricompartment endoprostheses in eight, unicompartment endoprostheses in seven, and tibial unicompartment hemiprostheses in two knees.

The complications that caused the exchange of the TKA were deep infection in nine, loosening or subsidence of prosthetic components in seven, severe instability in four, progressive arthropathy in the nonoperated compartment of the knee in

two demiarthroplasties, one fracture, and one malposition of the prosthetic components.

Final TKA. The TKAs that were revised to knee fusion included a hinged TKA in 36 patients (24 GUEPAR, six Walldius, five St. Georg, and one Shier); a stabilized TKA in seven (four Attenu-borough, two Sphero-centric, and one GSB), a tricompartment TKA in 31 (16 Freeman-Swanson, 11 Townley, three Total Condylar, and one Richard Maximal Contact), a bicompartment TKA in three (Geomedic), a medial and lateral unicompartment TKA in 11 (eight Marmor, two St. Georg Schlitten, and one Gunston-Hult), and finally a medial or lateral demiarthroplasty in three (Marmor, St. Georg Schlitten, and Savastano).

Reasons for TKA failure. A mechanical failure was seen in 25 patients, with loosening of components in 13, severe instability in five, fracture of the endoprosthesis in three, patellofemoral pain in two, and insufficient extensor muscle power in two.

An infectious failure was recorded in the medical charts of 66 patients. The criteria for diagnosing infection were not uniform, and some cases of low-grade septic arthritis with loosening were difficult to distinguish from sterile reactive loosening. Fifty-six of the infections were classified as proven deep infection because they fulfilled at least one of the following criteria used in this study:

1. Fistulation from the joint or adjacent bone.
2. Three or more positive tissue biopsy cultures, out of a total of five.
3. Septic infection with growth of the same bacteria in the blood and joint.
4. Two or more knee aspirations growing the same bacteria.

The diagnosis of proven deep infection was based on the occurrence of fistulas at the time of arthrodesis in 47 knees, previous periods of fistulas in three, more than two positive knee aspirations in three, growing *Staphylococcus aureus* in two and enterococci in one. Three infections were diagnosed on multiple tissue cultures growing *Staphylococcus epidermidis* in two and *Streptococcus faecalis hemolyticus* in one knee.

Forty-two of the proven deep infections started early (within three months of the TKA). Fifteen were fistulating infections. Two of these were associated with intraoperative complications—one femoral condylar fracture and one rupture of the patellar ligament. Two were revised with continuing fistulation. Fourteen early infections were associated with skin necrosis. One of these knees had an intraoperative thrombosis of the femoral artery at the level of the tourniquet, and another

had an intraoperative rupture of the patellar ligament. Four knees were revised, but all developed fistulas. Eight early infections started as a wound dehiscence. Four were revised, resulting in fistulating infections. Three early fistulating infections were secondary to revision—one patellectomy, one shortening of a collateral ligament, and one removal of Kirschner wires from a patellar osteotomy. Two early infections started as a septic arthritis. Revision was tried in one knee, resulting in a fistula.

Fourteen proven infections started *late* (after three months), six as a septic arthritis (three of these fistulated after revision). Five had a periarticular abscess that fistulated after incision, and three were late skin necroses with fistulas.

Ten knees had a clinical infection but did not fulfill any of the criteria, they were thus classified as *probable deep infection*. Three infections started as an acute septic arthritis, with single cultures from a knee aspirate growing *Staphylococcus aureus* in two and *Pseudomonas aeruginosa* in one. Three of the infections were of the chronic type, with rapid progressive bone resorption and loosening in two knees. Four probable infections had a wound dehiscence or postoperative skin necrosis.

Treatment of infection before arthrodesis. Twenty-nine infected TKAs had a prolonged period of antibiotic treatment before arthrodesis. Altogether, 56 attempts were made to revise the infection prior to arthrodesis, with the use of suction-irrigation drainage in 19 attempts, excision of fistulas in 18, incision of an abscess in ten, wound closure with a skin flap in five, temporary insertion of gentamicin beads in three, and synovectomy in one patient. Eight of the TKAs with proven infection were exchanged. The primary TKAs (three hinged, four tricompartment, and one unicompartment endoprosthesis) failed because of proven fistulating infection in six, proven septic arthritis in one, and a probable infection in one.

Surgical technique at arthrodesis. At the primary attempt at arthrodesis, a medial parapatellar incision was used in 47, a transligamentary horizontal incision in 20, and a lateral in three knees. In 21 patients the type of incision was not stated. All prosthetic components were removed. In all but ten knees, all bone cement was extracted during removal of the endoprosthesis. In two knees, remaining bone cement was extracted at a second stage. Usually, bone cement was extracted through the joint cavity, but in five knees a slot was made and in two a hole was made in the cortex of the femur and/or tibia. Wound closure was primary in 85, with a skin flap in two and a split skin graft in one. In two knees, a secondary wound closure

was used, and in four, the way of closure was not stated. The patella was partially resected in 20 knees. In six, the removed cancellous bone was locally transplanted, and in five, the remainder of the patella was pinned to the condyles. Total patellectomy was performed in 12 knees, and in ten of these the patellar bone was transplanted. Cancellous bone was transplanted from the iliac crest in 12 attempts and from locally excised bone in four. In one case, heterotopic bank bone was used.

Fixation at the primary attempt at knee arthrodesis was external in 82 and internal in nine knees (Table 1). The method used most often was external fixation with a Hoffmann-Vidal frame in 49 knees. A Charnley single frame with additional plaster of Paris was used in 36, and a Charnley double frame in four knees. Plaster alone was used once. Internal fixation was performed with an intramedullary nail in six, a Rush pin in one, and multiple staples in two knees. The arthrodeses with a Charnley single frame had an average frame fixation time of six weeks (range, two weeks to four months) and an overall mean fixation time, including after-treatment in plaster of Paris, of 3.9 months (range, two to 11 months). The arthrodeses performed with multiple pin fixators (Charnley double frame and Hoffman-Vidal) had an average fixation time in an external fixator of 3.1 months (range, one to seven months) and an overall mean fixation time, including after-treatment in plaster of Paris, of 4.5 months (range, two to 15 months).

A second attempt at arthrodesis was performed in 14 knees, with Hoffmann-Vidal fixation in nine, an intramedullary nail in four, and a Charnley frame in one attempt. A third attempt at arthrodesis was performed in three knees with the Hoffmann-Vidal fixator. In five of the later attempts, the patella was resected, and the remainder in four was fixed to the condyles with a screw. Cancellous bone was transplanted from the iliac crest in six and from locally excised bone in five. A corticocancellous sliding graft was used once.

Treatment of infection at arthrodesis. In cases of infection, systemic treatment with antibiotics before, during, and after arthrodesis was generally used. Forty-eight of the 56 knees with proven infection were treated in a one-stage procedure, with additional synovectomy in ten, suction-irrigation drainage in four, and temporary implantation of gentamicin-containing beads of bone cement (Septopal) in eight. Eight proven infections were treated in a two-stage procedure. After removal of the endoprosthesis, the knee was temporarily stabilized in plaster and the infection was treated, in four of these with gentamicin beads. In one knee, both suction-irrigation drainage and

TABLE 1. Fixation Methods and Fusion Rates

Fixation Method	Unstable Fusion		Stable Fusion		MV*	Total
	Pseudarthrosis	Fibrous	Fibrous	Osseous		
Plaster of Paris	1	—	—	—	—	1
Charnley single frame						
First attempt	18	7	1	10	—	36
Second attempt	—	1	—	—	—	1
Charnley double frame	2	—	—	2	—	4
Hoffmann-Vidal						
First attempt	10	3	1	16	2	32
Second attempt	3	—	1	3	—	7
Third attempt	—	—	1	1	1	3
H-V plus sagittal pins						
First attempt	3	—	1	5	—	9
Second attempt	2	—	—	—	—	2
Intramedullary nail						
First attempt	—	—	—	5	1	6
Second attempt	—	—	—	4	—	4
Internal osteosynthesis	2	—	—	1	—	3
Total	41	11	5	47	4	108

* MV = missing value: one amputated and three dead patients, result not classified.

implantation of gentamicin beads were used, and in another knee, gentamicin beads were implanted after removal of remaining bone cement at arthrodesis. The period between removal of the endoprosthesis and the arthrodesis was one month in all but two (two and ten months).

In four of the ten knees with probable infection, a synovectomy was performed during arthrodesis, and in one knee suction-irrigation drainage was added. In all ten knees, a one-stage procedure was used.

RESULTS

The 91 patients had a mean follow-up period from the latest attempted arthrodesis of 26 months, ranging from two days to 57 months. The results of four arthrodeses could not be classified. One patient with a hinged endoprosthesis infected by *Staphylococcus aureus* died two days after the arthrodesis from septicemia. Two patients died during treatment of unrelated diseases two and four months after the arthrodesis without any signs of failure or complication from the knee. The fourth patient with a fistulating infection from a tricompartment TKA had

an infected pseudarthrosis after two attempts to fuse the knee. A hinged TKA was then inserted, causing progressing infection and a skin necrosis. A final attempt to fuse the knee with an external fixator and sliding grafts resulted in continuing infection and an above knee amputation one month later.

FUSION RATES

Fifty-two of the remaining 87 patients had a fused knee at follow-up evaluation (Table 1). Forty-seven had osseous and five a fibrous healing. Four of the fibrous healings were only radiographically examined three to six months after surgery and showed no sign of overbridging callous; they were clinically stable three years later. One stable fusion remained radiographically fibrous two years after surgery. Thirty-five knees were unstable, with a clear radiographic pseudarthrosis in 25 and a fibrous healing with an instability of less than 10° in ten knees.

Three of the pseudarthrotic knees later had an above-knee amputation, and two

were treated by a hinged TKA. One of the latter is still *in situ* with a mobility of 10°, and one had a wound dehiscence and a fistulating infection, from which the patient expired. Six more patients expired during the follow-up period from unrelated diseases. In the 14 patients with two or more attempts at arthrodesis, eight finally had osseous and two fibrous stable fusions.

Only four clinics reported more than five patients each, 39 altogether, with fusion in 30. The remaining 48 patients with a classifiable result were reported from clinics each reporting less than six patients. Twenty-two of these were fused ($p < .01$) (statistical analysis by Clas Svenson, University Department of Statistics, Lund, Sweden).

Primary gonarthropathy. Eighteen of 34 knees with primary osteoarthritis and 25 of 45 knees with rheumatoid arthritis, as well as nine of the remaining 12 knees, were fused at follow-up evaluation.

Type of TKA. Twelve of 14 knees with a removed unicompartement endoprosthesis, 18 of 34 with a bi- or tricompartment TKA, and 22 of 43 with a stabilized or hinged TKA were fused at follow-up evaluation. The results of the primary attempt at arthrodesis related to the type of TKA removed are presented in Table 2. The fusion rate was higher at the primary attempt after unicompartement endoprostheses ($p < .05$) (statistical

analysis by Clas Svenson, University Department of Statistics, Lund, Sweden).

Type of TKA failure. Thirty-two of the 56 knees with proven deep infection and nine of the ten knees with probable deep infection were fused at follow-up evaluation. Of the remaining 25 knees, six became infected during arthrodesis, with only two fused at follow-up evaluation. Nine of the remaining 16 knees with biomechanic failures were fused at follow-up evaluation.

Fixation method. The use of a multiple pin fixator resulted in fusion in almost two-thirds and the use of a single frame fixator resulted in fusion in one-third of the primary attempts ($p < .05$) (Table 2) and of all attempts ($p < .01$) (Table 1). Nine attempts of intramedullary nail fixation fused.

The effects on fusion rates of fistulating infection, reduced bone stock due to intramedullary fixed stem endoprostheses, and poor fixation with single frame fixators and/or plasters are demonstrated in a Venn diagram (Fig. 1). Poor fixation after removal of a stem endoprosthesis with fistulating infection resulted in two fusions in 13 attempts. More stable fixation in 11 compartmental endoprostheses with complications other than fistulating infection resulted in nine fusions. An analysis of the Venn diagram shows that the method of fixation was of major importance, the type of TKA removed of some

TABLE 2. Fusion Rates After the First Attempt at Arthrodesis

Fixation Method	Type of TKA Removed						Total Fused	Total
	Hinged or Stabilized		Bi- or Tri-compartment		Unicompartiment			
	Fused	Total	Fused	Total	Fused	Total		
Charnley single frame	3	15	6	17	2	4	11	36
Multiple pin fixators	11	22	8	14	6	7	25	43
Intramedullary nail	2	2	2	2	1	1	5	5
Other methods	—	2	—	1	1	1	1	4
Total	16	41	16	34	10	13	42	88*

* Three patients were excluded, results not classified (expired).

importance, and the occurrence of a fistulating infection of no importance in determining the outcome of the arthrodesis.

Bone transplantation. Sixty-two attempts at arthrodesis with classifiable results were performed without bone transplantation, with fusion in 30. Thirty-seven attempts with cancellous bone transplantation at arthrodesis resulted in 22 fusions. The use of a patella graft in five attempts, heterotopic bank bone in one attempt, and a corticocancellous sliding graft in one attempt resulted in no fusions. Four of the six patients receiving a secondary cancellous bone transplantation because of delayed union fused osseously.

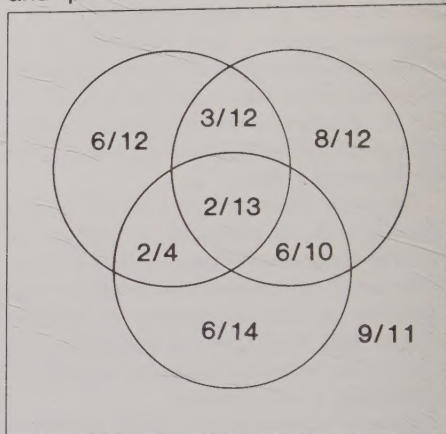
COMPLICATIONS

Two patients sustained a distal femoral fracture during removal of the TKA. One of these healed in a Hoffmann fixator and the other developed a pseudarthrosis with the same type of fixator but healed when revised with an intramedullary nail fixating both the fracture and the knee.

Complications were seen in 19 of the 57 attempts with a multiple pin fixator. Twelve attempts resulted in poor fixation, with fractured pins in two and loosening of the pins in ten. In seven of these, the pins were reinserted, and three finally fused. There were two superficial pin tract and wound infections and four deep infections in knees with mechanical TKA failures. Two of the latter were operative contaminations, and one was a pin tract infection resulting in pseudarthroses. One pin tract infection along a proximal pin fixating a postoperative femoral fracture contaminated a hip endoprosthesis, which had to be removed although the fusion healed. One case of permanent peroneal nerve palsy and one case of skin necrosis secondary to a bone transplantation with uneventful healing were seen two months after surgery. One patient with a successful femorotibial knee fusion had a painful patellofemoral pseudarthrosis that was successfully fused one year later.

Charnley fixator
and plaster

Fistulating
infection



Stem endoprosthesis

FIG. 1. This Venn diagram illustrates some factors influencing the fusion rate after the first attempt at arthrodesis. Three expired patients were excluded. For each subset, the number of fused through the total number of attempts is given.

Complications were seen in 14 of the 37 attempts with a Charnley single frame fixator. Nine attempts resulted in skin necrosis—three minor from pressure of the plaster, four minor wound edge necroses, and two major with fistulas from infectious flare-up. Only two of these fused. In five, loosening of the pins resulted in dislocation and failure. One superficial pin tract infection and two deep infections were seen in patients with mechanical TKA failure. Of the latter, one was an operative contamination and the other a pin tract infection that developed into osteitis and failure.

Four complications were seen in ten attempts with an intramedullary nail fixation. During rodding, the nail penetrated the tibial shaft in one attempt but was immediately repositioned. In another attempt, a tibial shaft fissure was seen one month after surgery. The fissure healed in a cast. One nail migrated

TABLE 3. Infection and Fusion After the First Attempt at Arthrodesis

<i>Infection After Arthrodesis</i>	<i>Fused</i>	<i>MV*</i>	<i>Total</i>
"Healed"***			
Proven infection†	22	—	41
Probable infection†	9	—	9
Active			
Proven infection	3	1	15
Probable infection	—	—	1
Secondary infection at arthrodesis	1	—	6
Total	35	1	72

* MV = missing value: one dead patient, result not classified.

** "Healed" denotes infection under control with treatment.

† For definition, see *Reasons for TKA failure* ("Materials and Methods").

proximally during healing and was reinserted one year later. Finally, there was one case of minor skin necrosis that healed uneventfully.

INFECTION

The effect on fusion rates of the treatment of infection is shown in Table 3. Thirty-one of 50 primary attempts where infection was brought under control fused, but only four of 21 with infection starting at or continuing after arthrodesis fused ($p < .01$).

Proven deep infection. Twenty-two of 29 patients treated by general antibiotics and a one-stage procedure had successful healing of the infection. The remaining seven had continuing fistulating infection. Two healed on continuous antibiotic treatment, three after repeated revisions, and two, with remaining bone cement, had continuing infection despite repeated revisions. Six of 11 patients treated by a one-stage procedure combined with synovectomy and/or suction-irrigation drainage had uneventful healing of the infection. One patient expired from septicemia (see above), and four patients had continuing infection. One healed sponta-

neously and another after revision with gentamicin beads. One patient with continuing infection contaminated her hip endoprosthesis, and the fourth patient with osseous healing fistulated, despite revisions and removal of an intramedullary nail.

Seven of eight patients receiving gentamicin beads in a one-stage procedure had uneventful healing. In one patient, a skin defect that could not be closed at the arthrodesis slowly healed at two years.

Four patients treated by a two-stage arthrodesis combined with systemic antibiotic treatment had continuing infection. Extraction of remaining bone cement, surgical revision, and insertion of gentamicin beads in two cases eventually resulted in healing.

Three of four patients treated by a two-stage arthrodesis with temporary insertion of gentamicin beads healed. The fourth patient developed a large skin necrosis caused by pressure from the luxated joint ends. The ensuing fistulating pseudarthrosis was revised with a hinged TKA.

Probable deep infection. Nine of ten patients with probable infection healed. One patient with a remaining fistula was revised twice by use of gentamicin beads with no effect, resulting in an above-knee amputation nine months later.

FUNCTIONAL RESULTS

For the final follow-up evaluation, a questionnaire was used to assess pain and activities of daily living (ADL) results. Thirteen patients were unavailable because of death, amputation, or reoperation at the time of the follow-up evaluation. Twenty-one of the 28 patients with unstable knees and 40 of the 50 fused patients attended the voluntary follow-up evaluation. The results are summarized in Table 4. Among patients with pain at rest, only slight pain was noted. Four patients with unstable knees regarded their pain at weight-bearing as being more than slight. Two patients with stable fusions and pain at weight-bearing had fibrous healing, and one had 15° of varus malalignment. The wheelchair-bound patient with a stable fusion was

immobilized because of general mutilating rheumatoid arthritis. One patient with radiographic osseous healing sometimes used a brace to protect her knee. The median walking distance was 10–50 m in patients with unstable knees and 500 m in patients with fused knees.

DISCUSSION

The introduction of compression arthrodesis by Charnley⁷ made primary knee fusion a safe procedure, with fusion in almost 100%.⁸ Close apposition of the resected condyles, proper fixation of the fragments, and compression are the advantages of this technique.⁷ The use of primary knee fusion declined as TKA was introduced. Currently, however, knee fusion is again increasingly used, but as a salvage procedure for TKA failures. Studies on arthrodesis for TKA failures show improving fusion rates as the technical problems of the multiple revised prosthetic knee are realized. The fusion rate is usually reported to be lower than in primary arthrodesis. Suggested reasons for this are the reduced metaphyseal bone stock with poor bone quality, inadequate technique of fixation, and persistent infection.^{3,6,11,21} Volumetric studies by Hankin *et al.*¹² have confirmed the clinical finding of a smaller metaphyseal bone loss when uni- and bicompartments endoprotheses are inserted, compared with tri-compartment, stabilized, and hinged TKAs. The use of excessive bone cement and the destructive process around the prosthetic device further reduce bone stock. In this study, as in most earlier reports, unconstrained or semiconstrained TKAs were found easier to convert to solid fusions than were constrained TKAs (Fig. 1, Tables 2 and 5).

The use of a single frame fixator with plaster was inadequate in this study, with fusion in only one-third. Contributing factors were a short average fixation period (six weeks), poor control of apposition and alignment, and pin tract infections. The multiple pin fixators, mainly the Hoffmann device with quadrilateral mounting according to Adrey and Vidal, were more effective with

TABLE 4. Summary of ADL Results

Statement	Unstable Fusion		Stable Fusion	
	No.	Total No.*	No.	Total No.*
Unsatisfied	6	20	1	39
Pain at rest (slight or more)	3	20	8	40
Pain at weight-bearing (more than slight)	4	20	2	39
Walking ability limited by arthrodesis	11	20	7	39
Able to ascend stairs	7	20	29	37
Able to rise from a chair	15	20	31	36
Support at walking	17	17	29	37
Wheelchair	3	20	1	38
Brace	19	21	1	40
In a home for disabled	7	21	—	39
Total		21		40

* Not all questionnaires were completely answered.

fusion in more than one-half (Table 1). The average compression period was, however, twice as long as for the single frame arthrodeses. The main problems were pin tract infection and loosening of the pins. The limited anteroposterior stability of the Hoffmann–Vidal fixator may have contributed to some failures. Brodersen *et al.*⁶ stated, however, that the type of fixator was not as important as retaining the device long enough, optimally ten weeks. Vahvanen²¹ reported better results with multiple pin fixators than with single frame devices. The same was reported by Hagemann *et al.*,¹¹ who also stated that failure to fuse was due mainly to technical inadequacy of the procedure.

Some of the limitations of the multiple pin fixators might be overcome by the use of a drill bit during insertion of the percutaneous pins to minimize heat necrosis of the bone,¹⁸ threaded pins for better fixation,^{4,5} titanium pins for better biocompatibility,¹ and careful postoperative attention to soft tissues and pin tracts.¹⁰ A two-plane fixator with ventral frames^{9,16} has shown a superior anteroposterior stability, and in one comparative study,

TABLE 5. Review of the Literature: Fusion Rates After the First Attempt at Arthrodesis

Authors	Unconstrained/ Semiconstrained TKA		Constrained TKA	
	Fused	Total	Fused	Total
Bigliani <i>et al.</i> 1983 ³	12	12	5	8
Brodersen <i>et al.</i> 1979 ⁶	29 (+3)*	36	5 (+1)*	9
Hagemann <i>et al.</i> 1978 ¹¹	5	7	4	7
Knutson <i>et al.</i> 1984 ¹⁷	7	7	9	12
Rothacker and Cabanela 1983 ¹⁹	27	31	9	12
Vahvanen 1979 ²¹	4	8	—	—
Total	84 (+3)*	101	32 (+1)*	48

Authors	Infected TKA		Noninfected TKA	
	Fused	Total	Fused	Total
Brodersen <i>et al.</i> 1979 ⁶	34	40	4	5
Hagemann <i>et al.</i> 1978 ¹¹	7	10	2	4
Knutson <i>et al.</i> 1984 ¹⁷	12	14	4	5
Rothacker and Cabanela 1983 ¹⁹	30	34	6	9
Vahvanen 1979 ²¹	1	1	3	7
Woods <i>et al.</i> 1983 ²²	16	16	9	11
Total	100	115	28	41

* Stable fibrous ankylosis.

improved fusion rates have been clinically verified.¹⁹

Intramedullary nail fixation was performed in ten cases, with uniformly good results and only one significant complication, the proximal migration of the nail during healing. This complication can be remedied by use of a locking-nail¹⁵ at reoperation.

A significant effect of cancellous bone transplantation on the fusion rate, as in cases of delayed fracture union, could not be demonstrated in this study. Apparently, better results were obtained for late cancellous bone transplantation in cases of delayed fusion.

Deep infection was the indication for knee fusion in three-fourths of this material, which is the same proportion usually reported (Table 5). The finding in the literature that infection does not reduce the likelihood of achieving fusion is supported in the present study (Table 5). In spite of this, a subset with particularly low fusion rate is active infection continuing after arthrodesis and failures becoming in-

fectured at arthrodesis (Table 3). Fusion was obtained in 31 of 50 knees where infection was brought under control at or before arthrodesis, and in four of 21 knees where infection started or continued after arthrodesis. The single most effective way of combating infection seemed to be the use of gentamicin beads in a one- or two-stage procedure in combination with systemic antibiotic therapy, with healing of the infection in almost all attempts. An optional benefit of a two-stage procedure is the possibility of completing the extraction of bone cement at the second stage if the radiographs indicate remaining bone cement, since this may otherwise create late complications with local infections, bone resorption, and sinus formation. The two-stage procedure with temporary gentamicin-bead treatment is well advised if internal fixation is contemplated and in cases needing bone transplantation, which could be performed when the antibiotic-containing beads are removed.

Kaufer and Matthews¹⁴ reported one successful resection arthroplasty after a failed Sphero-centric TKA. Usually, a pseudarthrosis does not function equally well because of instability, weakness, and pain at weight-bearing. Bigliani *et al.*³ reported that walking ability was improved as unstable fusions were converted into solid fusion. The authors' analysis of the ADL results support this finding. Furthermore, one-third of the patients with unstable knees needed nursing in a home for the disabled or chronically ill, and four patients not included in the functional follow-up evaluation had had an above-knee amputation. Finally, the need for a brace when walking poses a special problem for the rheumatoid patient with poor hand function.

This retrospective study reflects the average results obtained by many surgeons with varying experience in this kind of surgery. Four surgical units reporting more than five patients each achieved fusion in more than three-fourths, compared with the remaining units with fusion in less than one-half. The overall results could be improved as further experience with secondary knee fusion is gained. In recent reports focusing on secondary knee arthrodesis, fusion has been obtained in more than 90%.^{17,22} It should be possible, with further knowledge of indications, timing of knee revisions, treatment of infection, and further refinement of the surgical techniques and the fixating devices, to repeat these results in most centers with a special interest in TKA surgery.

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